Introducing:
GUIDELINES FOR
MINE WASTE DUMP AND STOCKPILE DESIGN

Editors:
Mark Hawley, Piteau Associates Engineering Ltd.
John Cunning, Golder Associates Ltd.
8 November 2017
Sponsorship

Large Open Pit Mine Slope Stability Project
LOP Sponsors
At time of initiating the Waste Dump Book
LOP Sponsored Books

- Guidelines for Open Pit Slope Design (Eds. Read and Stacey 2009)
- Guidelines for Evaluating Water in Pit Slope Stability (Eds. Beale and Read 2013)

- Guidelines for Design of Open Pit Mines in Weak Rocks (Eds. Martin and Stacey)
  - to be published in 2018.
Why do we need a book on Guidelines for Waste Dumps, Stockpiles and Draglines Spoil Design?
Why do we need a book on Guidelines for Waste Dumps, Stockpiles and Draglines Spoil Design?
Some Good Examples

Figure 1.2: View of the Bingham Canyon Mine and associated waste dumps, ca. 2010. Source: Rio Tinto Kennecott Copper

From Hawley and Cunning (2017)
Some Good Examples

Figure 1.3: View of waste dump at a mine in the Elk Valley region of British Columbia. Note backfill waste dumps (active) in centre and reclaimed (inactive) waste dumps on right. Source: J Cunning

From Hawley and Cunning (2017)
Some Good Examples

Figure 1.1: East Dump at the Antamina Mine, Peru, ca. 2010. Source: M Hawley. Published with the permission of Compañía Minera Antamina S.A.

From Hawley and Cunning (2017)
Some Good Examples – Dragline Spoils

Figure 1.8: Typical dragline spoil, Hunter Valley, Australia. Source: J Simmons

From Hawley and Cunning (2017)
Some Not So Good Examples

Figure 1.5: Aberfan coal tip failure, 21 October 1966. Source: M Jones and I Mclean (n.d.) *The Aberfan Disaster.* <http://www.nuffield.ox.ac.uk/politics/abernan/home2.htm>

From Hawley and Cunning (2017)
Some No So Good Examples
Mine Waste Dump Guidelines

• Previous Guidelines for mine waste dump design were prepared following disasters in UK (1970’s), USA (1975), Canada (Canmet 1977), and BC (BCMWRPRC 1990’s)

• The Large Open Pit project undertook Guidelines for pit slopes design and evaluating water in pit slopes, with a logical next step to be a Guideline on the mine waste dumps.

• At LOP request this included stockpiles and draglines spoils
The Guidelines Book Outline

A comprehensive and practical guide to the investigation, design, operation, monitoring, and closure of mine waste dumps, dragline spoils, and major stockpiles.

Preface and acknowledgements
1. Introduction
2. Basic Design Considerations
3. Waste Dump and Stockpile Stability Rating and Hazard Classification System
4. Site Characterisation
5. Material Characterisation
6. Surface Water and Groundwater Characterisation
7. Diversions and Rock Drains
8. Stability Analysis
9. Runout Analysis
10. Risk Assessment
11. Operation
12. Instrumentation and Monitoring
13. Dragline Spoils
14. Management of Acid Rock Drainage
15. Emerging Technologies
16. Closure and Remediation
Appendices
References
Index
The Guidelines Book Outline

• Appendix I - Summary of British Columbia Mine Waste Dump Incidents 1968–2005

<table>
<thead>
<tr>
<th>Reference number</th>
<th>BC NEM (2012) number</th>
<th>BCM/YMPRC (1999) event number</th>
<th>BCM/YMPRC (1999) record number</th>
<th>Date of event</th>
<th>Dump name</th>
<th>Failed volume (m³)</th>
<th>Runout distance from top (m)</th>
<th>Dump height (m)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>21 Nov 1969</td>
<td>A-29 A</td>
<td>200,000</td>
<td>800</td>
<td>100</td>
<td>OK</td>
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<tr>
<td>2</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>8 May 1971</td>
<td>A-29 B</td>
<td>1,000,000</td>
<td>2000</td>
<td>280</td>
<td>No starting, Okay, Wind and pore pressure</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 May 1974</td>
<td>A-29 C</td>
<td>400,000</td>
<td>400</td>
<td>100</td>
<td>No water at wrinkles.</td>
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<tr>
<td>3</td>
<td>421</td>
<td>421</td>
<td>421</td>
<td>1 May 1972</td>
<td>A-29 D</td>
<td>2,000</td>
<td>400</td>
<td>100</td>
<td>Very small volume, deposition spill in upper stage which is inhibiting High tide, not visible mobility. Site covered in 24hr, water stopped to drain. For bulk dump, in lower part.</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>5 May 1972</td>
<td>A-29 E</td>
<td>5,000</td>
<td>200</td>
<td>100</td>
<td>Very heavy snowfall, but ground frost important.</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>9 May 1972</td>
<td>A-29 F</td>
<td>400,000</td>
<td>200</td>
<td>130</td>
<td>Very heavy snowfall, but ground frost important.</td>
</tr>
</tbody>
</table>

Waste Dump incidents - Runout Volume with time

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The Guidelines Book Outline

- Appendix II - Summary of the 2013 Mine Waste Dump Survey

**Figure A2.2:** Summary of survey responses showing who the dump was designed by.

**Figure A2.3:** Type of dump or stockpile.

**Figure A2.4:** Method of dump construction.
Chapter 2: Basic Design Considerations
Mark Hawley

- Overview of design considerations and processes by stage of design for Waste Dumps and Stockpiles
- Key Site Selection Factors:
  - Regulatory and social
  - Mining
  - Terrain and geology
  - Environmental
  - Geotechnical
  - Fill material quality
  - Closure
- Objectives by Project Stage

INITIAL SITE SELECTION

CONCEPTUAL DESIGN

PREFEASIBILITY DESIGN

FEASIBILITY DESIGN

DETAILED DESIGN & CONSTRUCTION

OPERATION

CLOSURE
Chapter 2: Basic Design Considerations
Mark Hawley

- Study Requirements (Level of Effort) described by stage of design

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>Conceptual Design (Scoping)</th>
<th>Prefeasibility Design</th>
<th>Feasibility Design</th>
<th>Detailed Design and Construction</th>
<th>Operations</th>
<th>Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characterisation of Foundation Materials</td>
<td>Identification of major soil types and aerial distribution. Initial estimation of properties based on basic field descriptions, literature values and experience.</td>
<td>Definition of soil units and basic stratigraphy. Laboratory index testing to establish range of properties.</td>
<td>Supplemental index testing to expand database and confirm soil units and properties. Shear strength testing. In situ hydraulic conductivity testing in boreholes. Surface percolation/infiltration.</td>
<td>Ongoing index and shear strength testing of samples obtained during foundation preparation activities to validate soil types and design properties and improve database reliability.</td>
<td>Laboratory testing of soil samples from expansion areas.</td>
<td>+/- 10-15%</td>
</tr>
<tr>
<td>Geotechnical Characterisation of Fill Materials</td>
<td>Initial estimation of fill properties (density, shear strength, hydraulic conductivity) based on geological descriptions and reconnaissance-level geological mapping and rock/overburden characterisation, literature values and experience.</td>
<td>Preliminary evaluation of strength, durability and gradation of fill materials based on RLI and UCS testing of core, geomechanical core logging, and field exposures. Preliminary index testing of overburden materials. Preliminary characterisation of fill according to quality.</td>
<td>Gradation and shear strength testing of small scale samples. Estimate gradation using empirical techniques. Durability testing. Preliminary fill quality model and release schedule.</td>
<td>Gradation and shear strength testing of large-scale, bulk samples. Supplemental durability testing. Refine fill quality model and release schedule.</td>
<td>Ongoing testing of bulk samples to verify gradation and shear strength assumptions. Field verification and as-built documentation of gradation, quality and distribution and design compliance.</td>
<td>+/- 10-15%</td>
</tr>
<tr>
<td>Geochemical Characterisation of Fill Materials</td>
<td>Initial geochemical characterisation of waste rock and stockpile types based on geochemical descriptions and available information from early exploration work.</td>
<td>Preliminary geochemical classification of fill material types as potentially acid generating, neutral or acid consuming. Define and initiate laboratory testing program; acid-base accounting</td>
<td>Static and kinetic testing on samples of all potential acid generating materials. Ongoing static and kinetic testing; may include site trials.</td>
<td>Ongoing static and kinetic testing, may include site trials.</td>
<td>Detailed assessment of long-term durability. Verify design compliance and variances with respect to spatial distribution according to fill quality. Laboratory testing of overburden materials for use in closure and reconciliation.</td>
<td>+/- 15-25%</td>
</tr>
</tbody>
</table>

From Hawley and Cunning (2017)
Chapter 3: Waste Dump and Stockpile Stability Rating and Hazard Classification - Mark Hawley

- Introduction of new stability rating and classification system (WSRHC)
- 22 factors organized into 7 groups
- Large number of factors, but most are intuitive and easily obtained
- Boils down to 2 indices:
  - Engineering Geology Index (EGI)
  - Design and Performance Index (DPI)
- Spreadsheet version available

From Hawley and Cunning (2017)
Chapter 3: Waste Dump and Stockpile Stability Rating and Hazard Classification - Mark Hawley

- Stability Rating (WSR) 1 to 100
- 5 Hazard Classes (WHC)

From Hawley and Cunning (2017)
## Chapter 3: Waste Dump and Stockpile Stability Rating and Hazard Classification - Mark Hawley

<table>
<thead>
<tr>
<th>Stability Class</th>
<th>Level of Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waste dump and stockpile hazard class (WHC)</strong></td>
<td><strong>Investigation and Characterisation</strong></td>
</tr>
<tr>
<td><strong>Instability Hazard</strong></td>
<td></td>
</tr>
<tr>
<td><strong>I</strong></td>
<td>Basic desktop studies to establish initial stability rating and hazard classification; basic site reconnaissance to confirm key assumptions from desktop studies and plan field investigations; limited mapping and test pitting to verify subsurface conditions; material parameters based on literature experience and validated with limited field and laboratory index testing; initiate limited baseline environmental monitoring, condition drilling.</td>
</tr>
<tr>
<td><strong>II</strong></td>
<td>Desktop studies to establish initial stability rating and hazard classification; site reconnaissance to confirm key assumptions from desktop studies and plan supplementary field investigations; mapping and test pitting as required to verify subsurface conditions; material parameters based on literature experience and validated with field and laboratory index testing; initiate environmental baseline monitoring, condition drilling.</td>
</tr>
<tr>
<td><strong>III</strong></td>
<td>Comprehensive desktop studies to establish initial stability rating and hazard classification; comprehensive site reconnaissance to confirm assumptions from desktop studies; detailed mapping and subsurface investigations (likely including test pitting/stratigraphy and limited drilling and sampling); in situ instrumentation and testing and laboratory testing to verify foundation and fill material properties; initiate comprehensive baseline environmental monitoring, condition drilling.</td>
</tr>
<tr>
<td><strong>IV</strong></td>
<td>Detailed desktop studies to establish initial stability rating and hazard classification; comprehensive site reconnaissance to confirm assumptions from desktop studies; detailed, phased mapping and subsurface investigations (likely including test pitting/stratigraphy, geophysics, specialised drilling and sampling); in situ instrumentation and testing and laboratory testing to verify foundation and fill material properties to a high degree of confidence; initiate comprehensive baseline environmental monitoring, condition drilling.</td>
</tr>
<tr>
<td><strong>V</strong></td>
<td>Detailed desktop studies to establish initial stability rating and hazard classification; comprehensive site reconnaissance to confirm assumptions from desktop studies; detailed, phased mapping and subsurface investigations (likely including test pitting/stratigraphy, geophysics, specialised drilling and sampling); in situ instrumentation and testing and sophisticated and comprehensive laboratory index; show strength testing to establish foundation and fill material properties to a high degree of confidence; comprehensive baseline environmental monitoring program; condition drilling.</td>
</tr>
</tbody>
</table>
Chapter 4: Site Characterisation
Michael Etezad, John Cunning, James Hogarth and Geoff Beale

• Level of effort discussed as function of stage of project and level of risk
• Site Characterisation Study Areas:
  • Physiography and geomorphology
  • Geology
  • Natural hazards
  • Climate
  • Geotechnical

• Planning and Methods for Field Investigations
  • Drilling and in situ testing methods
  • Sampling

From Hawley and Cunning (2017)
Chapter 5: Material Characterisation
Leonardo Dorador, John Cunning, Fernando Junqueira and Mark Hawley

- Foundation Material Properties
  - Soils
    - Index properties and classification
    - In situ density
    - Shear strength
    - Hydraulic conductivity
  - Bedrock
    - Rock/rock mass characterisation and classification
    - Intact rock and discontinuity strength
    - Rock mass strength

<table>
<thead>
<tr>
<th>Material</th>
<th>Unified Soil Classification System (USCS) Group Symbol</th>
<th>Cohesion (kPa)</th>
<th>Effective Friction Angle Φ (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels, gravel with sand, alluvial deposits (high energy), well-graded sand, angular grains</td>
<td>GW, GP, GM, SW</td>
<td>0</td>
<td>30–45</td>
</tr>
<tr>
<td>Outwash (low energy), volcanic soil (lava)</td>
<td>GW, GP, GM, SW, SM, SP</td>
<td>0–50</td>
<td>25–40</td>
</tr>
<tr>
<td>Alluvial (low energy), uniform sand, round grains</td>
<td>SW, SM, SP, ML</td>
<td>0–25</td>
<td>15–30</td>
</tr>
<tr>
<td>Glacio-lacustrine</td>
<td>SP, SM, ML</td>
<td>0–140</td>
<td>15–35</td>
</tr>
<tr>
<td>Lacustrine soil (inorganic)</td>
<td>SP, SM, ML</td>
<td>0–10</td>
<td>5–20</td>
</tr>
<tr>
<td>Silty sand</td>
<td>SM</td>
<td>0</td>
<td>30–34</td>
</tr>
<tr>
<td>Till, silty clays, sand-silt mix</td>
<td>SM, ML</td>
<td>0–200</td>
<td>34–45</td>
</tr>
<tr>
<td>Clayey sands, sand-clay mix, volcanic soil (tephra)</td>
<td>SC, SM, ML</td>
<td>0–50</td>
<td>20–35</td>
</tr>
<tr>
<td>Silt (non-plastic) clayey silts</td>
<td>ML</td>
<td>0–30</td>
<td>30–35</td>
</tr>
<tr>
<td>Sandy clay, silty clay, clays (low plasticity)</td>
<td>CL, CL-ML</td>
<td>0–20</td>
<td>18–34</td>
</tr>
<tr>
<td>Clays (high plasticity), clayey silts</td>
<td>CH, MH</td>
<td>0</td>
<td>19–28</td>
</tr>
<tr>
<td>Silt loam, clay loam, silty clay loams</td>
<td>ML, GL, CL, MH, OH, CH</td>
<td>0–30</td>
<td>18–32</td>
</tr>
<tr>
<td>Lacustrine soil (organic)</td>
<td>GL, PT</td>
<td>0–10</td>
<td>0–10</td>
</tr>
</tbody>
</table>

From Hawley and Cunning (2017)
Chapter 5: Material Characterisation
Leonardo Dorador, John Cunning, Fernando Junqueira and Mark Hawley

- Waste Dump Material Properties
  - Rockfill
    - Index properties and classification
    - Geochemistry
  - Non-linear Shear strength functions based on large triaxial testing results

From Hawley and Cunning (2017)
Chapter 6: Surface Water and Groundwater Characterisation  -Geoff Beale

- Planning Surface Water and Groundwater Investigations
- Development of a Conceptual Hydrogeological Model

From Hawley and Cunning (2017)
Chapter 6: Surface Water and Groundwater Characterisation - Geoff Beale

• Hydrogeological Modeling of the Dump/Stockpile and Foundations
  • Water balance, quantity and quality
  • Pore pressure modelling

Figure 6.2: Illustration of fragmentation on an end dumped surface. Source: G. Beale

From Hawley and Cunning (2017)
Chapter 7: Diversions and Rock Drains
James Hogarth, Andy Haynes and John Cunning

• Diversion Channels
• Rock Drains
  • Based on original CANMET Rock Drain Research Program (1992–1997)
• Other drainage elements
  • Drainage Blankets
  • French Drains
  • Chimney Drains
  • Toe Drains

Figure 7.1: View of segregation in a nominally 50 m high waste rock dump, with coarser material at toe. Source: J. Hogarth

From Hawley and Cunning (2017)
Chapter 8: Stability Analysis
Mark Hawley, James Hogarth, John Cunning, Andy Haynes

- Factors Affecting Stability
- Suggested Acceptance Criteria

From Hawley and Cunning (2017)
Application of Acceptance Criteria

From Hawley and Cunning (2017)
Chapter 8: Stability Analysis
Mark Hawley, James Hogarth, John Cunning, Andy Haynes

- Failure Modes
  - Waste materials, foundations and liquefaction
- Analysis Techniques
  - Methods of static limit equilibrium
  - Probability of failure
  - Seismic/pseudo-static analysis
  - Numerical methods

From Hawley and Cunning (2017)
• Evaluation of the consequence of a mine waste dump failure by considering the potential distance that runout debris may travel should failure of the dump occur
Chapter 9: Runout Analysis
Oldrich Hungr

- Material Properties for runout
- Slide initiation
- Dynamic Runout Analysis and Prediction (2 and 3D)
- Protection Measures
- Example Analysis

From Hawley and Cunning (2017)
Chapter 10: Risk Assessment
Brian Griffin

- Risk Assessment Processes applicable to Mine Waste Dumps
- Risk Management Process
- Analysis, Mitigation and Management

From Hawley and Cunning (2017)
Chapter 11: Operations
Andy Haynes and Geoff Beale

- Dump and Stockpile Management Plans
- Foundation Preparation
- Water Management
- Material Management
- Concurrent reclamation
- Crest Advance Rate Guidelines

From Hawley and Cunning (2017)
Chapter 12: Instrumentation and Monitoring
James Hogarth, Mark Hawley and Geoff Beale

- Visual inspections
- Displacement monitoring
- Monitoring Guidelines

- Surface water and groundwater monitoring
Chapter 12: Instrumentation and Monitoring
James Hogarth, Mark Hawley and Geoff Beale

- Monitoring and inspection guidelines linked to Hazard Class (WHC)

<table>
<thead>
<tr>
<th>Waste dump and stockpile hazard class (WHC)</th>
<th>Waste dump and stockpile stability rating (WSR)</th>
<th>Monitoring methods</th>
<th>Inspection requirements</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>80–100</td>
<td>Visual</td>
<td>Operations</td>
<td>Daily visual inspection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Geotechnical</td>
<td>Monthly visual inspection</td>
</tr>
<tr>
<td>II</td>
<td>60–80</td>
<td>Visual</td>
<td>Operations</td>
<td>Visual inspection and monitoring at the start of each shift (every 12 h)</td>
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<tr>
<td></td>
<td></td>
<td>Basic instrumentation (manual wireless extensometers, crack monitors, tell-tales, manually monitored prisms (monitoring frequency weekly-bimonthly))</td>
<td>Geotechnical</td>
<td>Weekly visual inspection; monthly data review</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Independent reviewer</td>
<td>Every 12–24 months</td>
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<tr>
<td>III</td>
<td>40–60</td>
<td>Visual</td>
<td>Operations</td>
<td>Visual inspection and monitoring every 6 h (twice per shift)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Basic instrumentation (manual wireless extensometers, crack monitors, tell-tales, manually monitored prisms (monitoring frequency daily-monthly))</td>
<td>Geotechnical</td>
<td>Daily visual inspection; weekly data review</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Independent reviewer</td>
<td>Annual</td>
</tr>
<tr>
<td>IV</td>
<td>20–40</td>
<td>Visual</td>
<td>Operations</td>
<td>Visual inspection and monitoring every 4 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automatic, continuous (telemeasured) wireless extensometers, LDM, RTS, SSR</td>
<td>Geotechnical</td>
<td>Visual inspections every 12 h; continuous (24/7) remote surveillance, biweekly data review</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Independent reviewer</td>
<td>Semi-annual</td>
</tr>
<tr>
<td>V</td>
<td>0–20</td>
<td>Visual</td>
<td>Operations</td>
<td>Visual inspection and monitoring every 2 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automatic, continuous (telemeasured) wireless extensometers, LDM, RTS, SSR</td>
<td>Geotechnical</td>
<td>Visual inspections every 8 h; continuous (24/7) remote surveillance, daily data review</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Independent reviewer</td>
<td>Quarterly</td>
</tr>
</tbody>
</table>

From Hawley and Cunning (2017)
Chapter 12: Instrumentation and Monitoring
James Hogarth, Mark Hawley and Geoff Beale

- Example of TARPS (response framework), linked to Waste Dump and Stockpile Hazard Class

Table 12.3: Example trigger action response plan (TARP) for a waste dump monitored using wireline extensometers

<table>
<thead>
<tr>
<th>Alert</th>
<th>Green</th>
<th>Yellow</th>
<th>Orange</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform condition</td>
<td>No new tension cracks; no recent movement on old tension cracks</td>
<td>Existing cracks opening and new tension cracks developing close to the crest</td>
<td>Cracking extends well behind the crest; open cracks; obvious differential settlement and/or development of steps or grabens on the platform</td>
<td>Rapidly coalescing, arcuate cracks that extend well behind the crest; deep, open tension cracks and/or grabens; platform not trafficable</td>
</tr>
<tr>
<td>Crest, face and toe condition</td>
<td>Normal toe, face and crest geometry; no toe spreading or heaving, face bulging, crest over-steepening or excessive ravelling</td>
<td>Minor changes in dump geometry (minor toe spreading/heaving, face bulging, crest over-steepening); minor face and crest ravelling</td>
<td>Pronounced toe spreading/heaving, and/or face bulging; substantial over-steepening of crest; small sliver failures, active face and crest ravelling/breakback</td>
<td>Extensive toe spreading/heaving and/or face bulging; active face and crest slumping/ravelling; frequent sliver failures, active instability</td>
</tr>
<tr>
<td>Deformation rate</td>
<td>&lt;X mm/h, extensometer</td>
<td>Rate of movement &gt;X mm/h and &lt; Y mm/h, rate increasing, extensometer monitoring</td>
<td>Rate of movement &gt;Y mm/h and &lt;Z mm/h, rate increasing, extensometer monitoring</td>
<td>Rate of movement &gt;Z mm/h, rate increasing</td>
</tr>
</tbody>
</table>

From Hawley and Cunning (2017)
Chapter 13: Dragline Spoils
John Simmons and Robert Yarkosky

- Operational Characteristics

Operating characteristics and terminology for draglines. Source: J Simmons

From Hawley and Cunning (2017)
Chapter 13: Dragline Spoils
John Simmons and Robert Yarkosky

- Dragline Operating methods
- Instability mechanisms

From Hawley and Cunning (2017)
Chapter 13: Dragline Spoils
John Simmons and Robert Yarkosky

- Inputs to stability analysis
- What can go wrong
- Methods for stability analysis

From Hawley and Cunning (2017)
Chapter 13: Dragline Spoils
John Simmons and Robert Yarkosky

- Stability analysis techniques

From Hawley and Cunning (2017)
Chapter 14: Management of ARD
Ward Wilson

- Principles of Acid Rock Drainage (ARD) and Metal Leaching (ML)
  - Drivers of ARD
  - Geochemical weathering processes
  - Climate
  - Dump structure and hydrology
  - Oxygen and water transport
- Review of Prevention and Control
  - Segregation
  - Blending
  - Encapsulation
  - Barriers and seals
  - Subaqueous disposal

From Hawley and Cunning (2017)
Chapter 15: Emerging Technologies
Ward Wilson

- Co-disposal techniques
  - Waste rock in tailings
  - Tailings in waste rock
  - Layered co-mingling; cells
  - Paste rock and mixtures of waste rock and tailings
  - Blending
  - Progressive sealing

Table 15.1: Forms of co-disposal

<table>
<thead>
<tr>
<th>Co-disposal type</th>
<th>Increasing degree of mixing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneous mixtures – waste rock and tailings are blended to form a homogeneous mass: 'paste rock'</td>
<td></td>
</tr>
<tr>
<td>Pumped co-disposal – coarse and fine materials are pumped to impoundments for disposal (aggregation occurs on deposition)</td>
<td></td>
</tr>
<tr>
<td>Layered co-mingling – layers of waste rock and tailings are alternated</td>
<td></td>
</tr>
<tr>
<td>Waste rock is added to a tailings impoundment</td>
<td></td>
</tr>
<tr>
<td>Tailings are added to a waste rock pile</td>
<td></td>
</tr>
<tr>
<td>Waste rock and tailings are disposed in the same topographic depression</td>
<td></td>
</tr>
</tbody>
</table>

Source: After Wiskland et al. (2006). © Canadian Science Publishing or its licensee.

Figure 15.5: Layered co-mingling of tailings and waste rock. Source: W. Wilson

From Hawley and Cunning (2017)
Chapter 16: Closure and Reclamation
Björn Weeks and Eduardo Salfate

• Approach to Closure and Reclamation Planning
• Closure criteria
  • Design life
  • Water quality
  • Geotechnical
  • Surface water management
• Geochemical stability
• Physical stability
• Erosion
• Revegetation

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In Closing

- The Guidelines for Mine Waste Dump and Stockpile Design book is now published and available for use
- Staff from mining industry sponsor sites have received the book and are starting to use it
- We encourage and look forward to mine waste dump papers at Tailings and Mine Waste and at other conferences